A RADIOCARBON DATED POLLEN DIAGRAM FROM THE ALLEGHENY PLATEAU OF NEW YORK STATE

RAY W. SPEAR AND NORTON G. MILLER

THE GENERAL PATTERN of late Quaternary vegetation change in the northeastern United States has been known for some time, but many chronological and interpretational details of the pollen record of this region still remain to be worked out. In New York State early studies (Cox, 1959; Deevey, 1943; McCulloch, 1939) established that late-glacial spruce-pine communities were replaced by postglacial forests rich in pine, which in turn gave way to forest communities with varying percentages of deciduous trees and hemlock. Few radiocarbon dates are available for these or earlier events, and their documentation by detailed pollen diagrams is inadequate for most parts of the state. For these reasons, a site in west-central New York, which we have named Belmont Bog, was selected for study.

Previous work in western New York (Miller, 1973) provides pollen diagrams with which to correlate results. Comparison with one diagram in particular, that from the Genesee Valley Peat Works, which is located 2 km. east of Belmont Bog, has allowed local and regional differences in the pollen record to be distinguished. The pollen diagram from the Peat Works has been difficult to interpret because the top of the deposit is truncated and because spruce zone assemblages contain abundant herb pollen. New data from Belmont Bog permit a reevaluation of these problems.

Sediments from Belmont Bog, which presumably is situated on Olean drift, the oldest recognized Wisconsinan till in the Northeast, contain seven pollen zones. Six levels in the deposit were radiocarbon dated, and where the sedimentation rate could be determined accurately, pollen influx values were calculated. Otherwise, absolute pollen frequencies are presented.

The record shows that tundralike vegetation existed around both sites for an estimated 3900 years (16,400–12,500 yrs. B.P.[1]) and was followed by a briefer period (12,500–11,000 yrs. B.P.) of open spruce woodland. About 11,000 yrs. B.P., pines began to dominate the vegetation, reaching maximum numbers 10,100 yrs. B.P. Hemlock replaced pine as the dominant forest tree about 8400 yrs. B.P. Surface samples indicate that the present virgin forests at Tionesta Scenic Area and Cook Forest in northwestern Pennsylvania are very similar to those that existed during later postglacial time in southwestern New York.

THE SETTING

Belmont Bog is located at 42°15′N and 77°55′W in Allegany County, New York. The bog covers an area of 2 ha. and is situated in the Phil-

[1] yrs. B.P. = radiocarbon years Before Present.

lips Creek Valley, 6.4 km. east of the Genesee River and 6.1 km. east of Belmont. The bog surface is at an elevation of 497 m.

Regional Glacial Geology

The oldest Wisconsinan deposit in western New York is the Olean drift (MacClintock & Apfel, 1944), the age of which is not known precisely. However, since Olean till overlies peat dated at 63,900 ± 1700 yrs. B.P. (Muller, 1964; Dreimanis & Goldthwait, 1973), the maximum age of the drift can not be greater than this.

On the western margin of the Salamanca re-entrant, an unglaciated area in southern Cattaraugus and Allegany counties, drift younger than the Olean has been distinguished (MacClintock & Apfel, 1944). The margin of this drift sheet has been traced continuously from the Kent terminal moraine in Ohio, and there is general agreement that Kent till is of late Wisconsinan (Woodfordian) age. Wood from a lacustrine deposit overlain by Kent till near Cleveland, Ohio, has been dated at 23,500 yrs. B.P., establishing a maximum age for the Kent advance (White, 1969).

The Lake Escarpment and Valley Heads moraines mark the next major Wisconsinan ice advance in New York State. Dreimanis and Goldthwait (1973) give the age of these moraines as early Cary. Connally and Sirkin (1973) accept an early Cary age and note that ice apparently remained at the Valley Heads position while retreating in the far western part of the state. Final withdrawal of ice from the Valley Heads position occurred prior to 14,900 ± 450 years ago (Calkin, 1970).

Glacial Geology of Allegany County

Allegany County is in the Genesee section of the glaciated Allegheny Plateau (Coates, 1974). Except for a small portion in the southwest corner (a part of the Salamanca re-entrant), the county was completely ice-covered during portions of the Wisconsinan. South of the town of Belvidere, Olean drift covers the valley of the Genesee River and surrounding uplands, including the site of Belmont Bog. The ice sheet which deposited this drift advanced from the northeast and receded northward unevenly (Muller, 1957). In the valleys active ice tongues retreated by backwasting, which often resulted in deposition of marginal kame terraces. Belmont Bog and the nearby Genesee Valley Peat Works are on such a kame terrace. The kame terrace near Belmont Bog is pitted with several kettles. The atypical shape of the basin and its depth profile (FIGURE 1) suggest the coalescence of two smaller basins.

As Olean ice retreated, a proglacial lake formed in the Genesee River Valley. This lake, Lake Wellsville, was about 24 km. long and had an outlet 1602 ft. above sea level which emptied into the Allegheny River watershed (Muller, 1957). Since the lower part of Phillips Creek Valley was undoubtedly flooded, the shore of Lake Wellsville must have

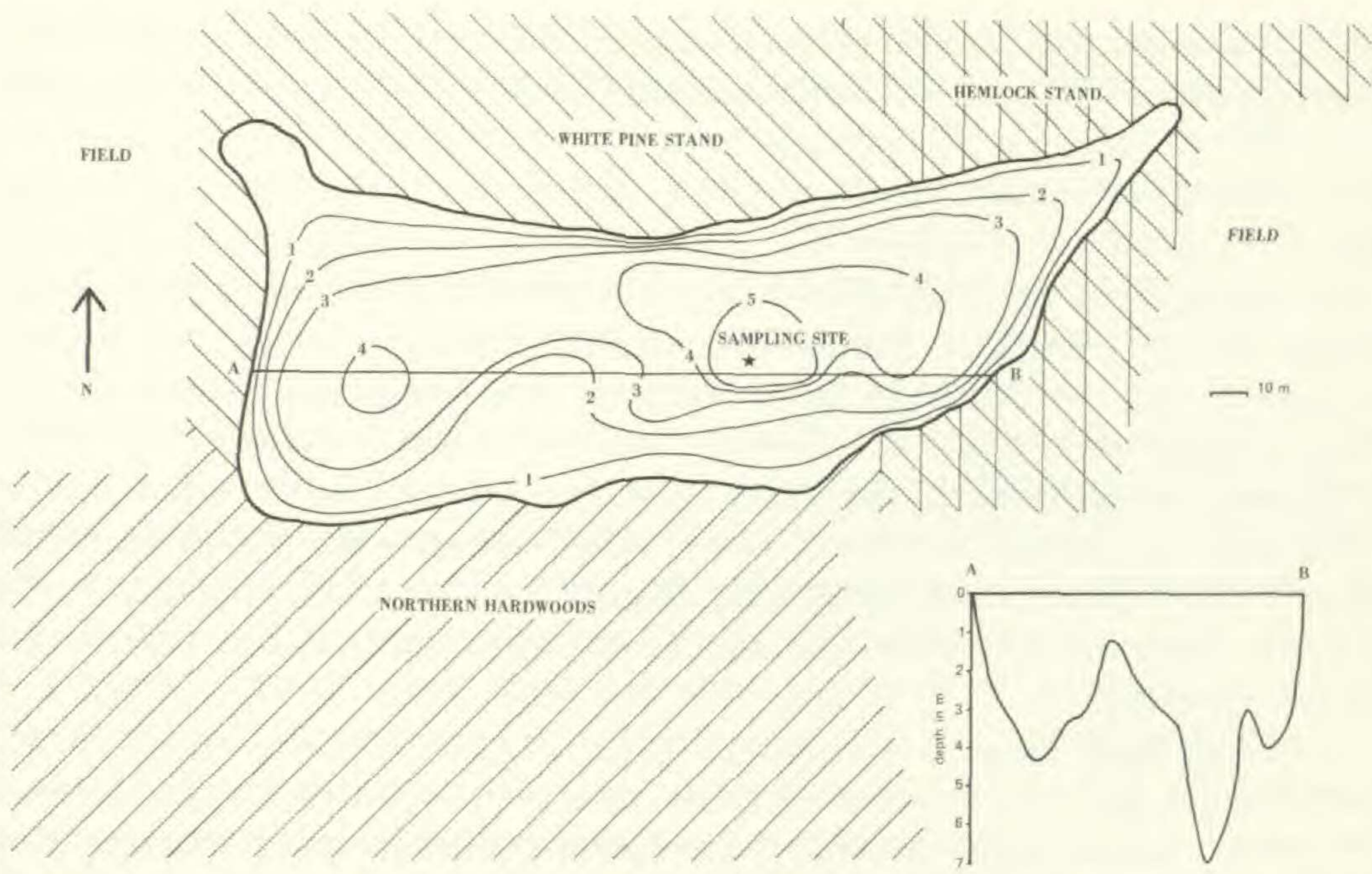


FIGURE 1. Basin of Belmont Bog showing depth contours (1 m. intervals), depths along east-west transect (A-B), and surrounding vegetation.

been close to Belmont Bog. After the ice retreated past Black Creek near Belfast, Lake Wellsville drained.

Kent drift covers the northern third of Allegany County. A lobe of the Kent ice advanced up the Genesee River Valley to within 4.8 km. of Belmont Bog and reestablished proglacial Lake Wellsville. Once the Black Creek outlet had reopened, Lake Wellsville drained and proglacial Lake Belfast-Filmore formed in the Genesee Valley. The Lavery drift and moraines recognized by Fullerton (1971) at East Rushford in the Genesee River Valley are thought by Muller (1957) to be deposits of a major stillstand in the recession of Kent ice.

During the Valley Heads advance, the ice sheet entered the northeastern corner of Allegany County to a point 10 km. south of Dansville. The margin of this ice sheet was about 35 km. northeast of the site of Belmont Bog. In the Genesee River Valley the Valley Heads terminal moraine is located at Portageville just north of Allegany County. A series of at least ten proglacial lakes formed in the Genesee Valley as the ice retreated northward to Mount Morris in Livingston County (Fairchild, 1908).

VEGETATION OF ALLEGANY COUNTY

Sketchy information exists about the forest vegetation of Allegany County prior to settlement by European man. Child (1875) and Minard (1896), who gathered reports from early settlers, indicate that white pine (*Pinus Strobus*) predominated in the forest and actually hindered clearing by its abundance. Hemlock (*Tsuga canadensis*), oak (*Quercus* spp.),

ash (*Fraxinus* spp.), elm (*Ulmus* spp.), chestnut (*Castanea dentata*), cucumber tree (*Magnolia acuminata*), and hickory (*Carya* spp.) were also common. Forests on bottomlands contained butternut (*Juglans cinerea*), buttonwood (*Platanus occidentalis*), cottonwood (*Populus* spp.), and elm.

A report from 1827 by a surveyor, Joseph Jones, recorded forest trees found in the Caneadea Indian reservation (Minard, 1896), which was located 23 km. north-northwest of Belmont Bog along the Genesee River. Bottomlands with alluvial soil had forests of elm, butternut, sycamore (*Platanus occidentalis*), and plum (*Prunus* spp.). Sandy loam soil of tablelands supported forests of white pine, white oak (*Quercus alba*), sugar maple (*Acer saccharum*), and birch (*Betula* spp.). Highlands with gravelly clay soil had pine and oak forest with chestnut and soft maple (*Acer rubrum*).

Original land surveys sometimes give a good description of forest composition and the names of witness trees. Unfortunately, original survey notes which might provide information useful in reconstructing presettlement forests apparently no longer exist for the eastern part of Allegany County where Belmont Bog is located. Gordon (1940), using original land survey data, topographic maps, soil surveys, historical accounts, interviews with old settlers, and field reconnaissance, has reconstructed the presettlement forest cover of adjacent Cattaraugus County. He recognized and mapped the following four major forest types which once covered most of that county. (Allegany County, which adjoins the eastern border of Cattaraugus County, no doubt had a similar forest cover.)

(1) Hemlock-white pine-northern hardwood forest covered the greatest area (see also Bray, 1915; Braun, 1950). The dominant trees were hemlock and beech (*Fagus grandifolia*); less frequent were sugar maple, yellow birch (*Betula lutea*), red maple (*Acer rubrum*), black birch (*Betula lenta*), and black cherry (*Prunus serotina*). Gordon (1940) recognized a separate Beech-maple component in Hemlock-white pine-northern hardwood forest, although he was unable to differentiate between the original distribution of the two and had to map them as one unit. Beech-maple forest occurred on the better drained soils of ridge tops, and dominant trees were sugar maple, beech, basswood (*Tilia americana*), white ash (*Fraxinus americana*), black cherry, and white pine. Beech-maple forest graded into (2) Mixed mesophytic forest, which occurred on well-aerated, moist soils. Dominant trees were red oak (*Quercus rubra* var. *borealis*), beech, chestnut, red maple, black birch, white ash, and black cherry. Cucumber tree, white oak, white pine, basswood, bitternut hickory (*Carya cordiformis*), sugar maple, hop hornbeam (*Ostrya virginiana*), and striped maple (*Acer pensylvanicum*) were less common species. Communities of Mixed mesophytic forest were transitional between Beech-maple and (3) Oak-chestnut forests, which occurred on high ridges and south and southwest slopes with dry soils. Dominant trees were white oak, red oak, chestnut, chestnut oak (*Quercus Prinus*), and

black oak (*Quercus velutina*). White pine, red maple, pignut hickory (*Carya glabra*), pin cherry (*Prunus pensylvanica*), black gum (*Nyssa sylvatica*), dogwood (*Cornus* spp.), and sassafras (*Sassafras albidum*) were less important. (4) White pine-American elm swamp forest occurred on river flats and flood plains. In addition to white pine and American elm (*Ulmus americana*), other common trees in the canopy were black ash (*Fraxinus nigra*), swamp oak (*Quercus bicolor*), red maple, hemlock, yellow birch, and white ash.

Goodlett and Lyford (1963) recognized two types of second-growth forest in the area immediately east of Allegany County. In the first, Northern hardwood, sugar maple, beech, basswood, hemlock, and white ash dominate. Red oak, red maple, yellow birch, and black cherry are less frequent, although they can be locally abundant. Gordon (1937) and Taylor (1928) have described the same type of secondary forest in Cattaraugus County. Gordon (1937) concluded that forests of this type occur in areas once occupied by presettlement hemlock-beech-northern hardwood and beech-maple forest communities. In present-day secondary Northern hardwood forest, hemlocks and white pines are greatly reduced in number because they were extensively cut for tanbark and lumber. The other kind of secondary forest recognized by Goodlett and Lyford (1963) is Oak forest. White oak characterizes this forest type, and red oak, white pine, black oak, chestnut oak, and large-toothed aspen (*Populus grandidentata*) are other dominants. Gordon (1937) recognized that this kind of oak forest replaced oak-chestnut, mixed mesophytic, and white pine presettlement forest communities in Cattaraugus County.

Flora and Vegetation of the Belmont Bog Area

A survey of forests in the Phillips Creek Valley was undertaken to establish the nature of forest vegetation near Belmont Bog. To determine importance values for dominant trees, two sets of thirty quarter points (Phillips, 1959) were done along transects on north- and south-facing slopes 1 km. south and 1.5 km. northwest of the bog respectively (Appendix A).

The north-facing slope is covered with forest of the Northern hardwood type. White oak is absent. Hemlock is in general less abundant than expected but is frequent on moist lower slopes with yellow birch. Sugar maple is abundant toward the top of the ridge. A deep ravine with what appears to be very old or possibly virgin forest was located at the end of the transect. The vegetation in this ravine appears similar to what Lewin (1974) has described as occurring in undisturbed ravines of the southern Finger Lakes region. A hemlock tree 100 ft. tall and 2 ft. in diameter at breast height was found near the top of this ravine.

Disturbed oak forest covers the south-facing slope. In this white oak is dominant; red oak is subdominant. The only hickory found was *Carya ovata*. No white pines occurred on the slope. The area had been lumbered within the last few decades, and most large trees had split trunks that

were unsuitable for timber. Tree tops and stumps littered the ground and the canopy was open.

A set of fifty quarter points was also done in forests immediately surrounding the bog to determine the dominant trees (see APPENDIX A). In sampled communities white pine was the most important tree, followed by hemlock, red maple, sugar maple, black cherry, beech, yellow birch, and red oak.

Although the quarter points have been tabulated in one unit, the forest can be divided into three parts (FIGURE 1). The first corresponds to stands of Northern hardwood forest. In it dominant trees are hemlock, sugar maple, red maple, beech, black cherry, red oak, and yellow birch. Seedlings and transgressives of nearly all these species can be found, and hence it seems to be a self-perpetuating unit. The other two units, one rich in hemlock and the other in white pine, are segregates of the Hemlock-white pine-northern hardwood forest type. Gordon (1937) reports that white pine or white pine mixed with hemlock occupied lower slopes, benches, and gravel terraces in the Allegheny River Valley. Similar stands of pure white pine or hemlock may have originally grown on the kame terrace on which Belmont Bog occurs. The hemlock unit occupies the eastern margin of the bog. Hemlock is dominant and few individuals of beech, yellow birch, and red maple were found. The transgressives are all hemlock trees. A thick layer of hemlock needles blankets the ground and no herbs have become established. The white pine unit consists of forest communities on the western and northern margins of the bog. The white pines appear even-aged and are mixed with a few black cherry, red maple, quaking aspen (*Populus tremuloides*), and red oak trees. There are a few young white pines in the subcanopy, but there are no seedlings of this species. Beech, hemlock, sugar and red maples are established under the white pine and probably will replace it in the next few hundred years, barring fire or windfall.

Compared with other bogs in western New York, the peat at Belmont Bog supports a very limited diversity of species. Trees, shrubs, and herbs around the margin are typical of bogs elsewhere in the region, but black spruce (*Picea mariana*) and tamarack (*Larix laricina*) are notably absent. Except for a marginal ditch, a sphagnum mat fills most of the basin. On it is established a leatherleaf (*Chamaedaphne calyculata*) heath. A few small white pine trees are growing on the mat. Red chokeberry (*Pyrus floribunda*), cotton grass (*Eriophorum virginicum*), pitcher plant (*Sarracenia purpurea*), and cranberry (*Vaccinium Oxycoccos*) are the only other common plants.

The flora of the Belmont Bog area is given in APPENDIX B.

LAND USAGE AND DEVELOPMENT

Child (1875) and Minard (1896) provide histories of the European settlement of Allegany County. Before the late eighteenth century, the Seneca Indians inhabited the area. They presumably had little effect on

the vegetation except along the alluvial flats of the Genesee River, where grassland was burned to enable cultivation of corn, beans, squash, and gourds.

Belmont Bog is located in a tract of 100,000 acres, 26 miles long and 6 miles wide, which was first acquired by John B. Church of New York. Settlement of the tract was slow. The region did not really flourish until the Genesee Valley Canal, an offshoot of the Erie Canal, and the Erie Railroad reached it. Owing to a lack of transportation, the lumber industry did not begin to develop until 1851, when the railroad reached Belvidere. After that, the area was extensively lumbered and burned over. Farming became important following depletion of the forests. Wheat, oats, and potatoes were the main crops, and dairy farming was very widespread. Only a few working farms are now left in the northeast section of the Town of Amity, where Belmont Bog is located.

MATERIALS AND METHODS

BELMONT BOG. Field work at Belmont Bog was carried out during the summers of 1973 and 1974. The basin was probed to determine the depth and nature of sediments along an east-west transect, the longitudinal axis of the basin. Depth along the transect (see FIGURE 1) was tested every 10 m. by pushing a Hiller sampler to the base of the deposit. Every 50 m., a complete column of sediment was collected and examined to determine extent and unique features of the peat, gyttja, and clay. Depth across the basin was determined by three north-south transects perpendicular to the main one. One final transect was used to establish depth in the northeastern bay of the bog.

A sampling site was selected 142 m. from the western edge of the bog and 5 m. north of the east-west transect. Peat and gyttja were sampled with a Hiller borer. A Davis sampler head attached by an adapter to Lichtwardt rods (Lichtwardt, 1952) was used to sample clay. Extruded samples were wrapped in plastic film and aluminum foil and stored at low temperatures until they were subsampled in the laboratory. A screw (shipwright's) auger (4.9 cm. in diameter, 50 cm. long) attached to Lichtwardt rods was used to collect the deepest clays. This type of sampler presents problems with deformation and contamination of sediment, but it was the only means by which to penetrate the extremely compact clays at the base of the deposit. The clay, which collected in the worm of the auger, was cleaned of surface contaminants by cutting off and discarding the outermost portions.

Samples for radiocarbon dating were collected with the Davis and Hiller samplers. Owing to small diameter chambers, repetitive sampling was necessary to collect sufficient material. Sampling was confined to an area not more than 1.5 m. from the coring site. Approximately twenty peat or gyttja samples were obtained in 5 cm. lengths from each of the following depths: 0.47–0.52 m., 1.43–1.48 m., 2.47–2.52 m., 3.45–3.50 m., and 3.70–3.75 m. These were dessicated and sent to the radiocarbon

laboratory at Heidelberg University (West Germany) for analysis. Organic clay samples were submitted to the radiocarbon laboratory at the University of Wisconsin's Center for Climatic Research. Approximately forty repetitive samples, each 5 cm. in length, were collected with the Davis corer at both 4.70–4.75 m. and 5.68–5.73 m. The lowest sample contained too little organic matter for dating.

Standard methods for deflocculation, removal of siliceous materials, and acetolysis described in Faegri (1975) were used to concentrate pollen and spores present in the samples. A uniform volume of sediment from all sampled levels was processed. This was accomplished by packing sediment into a glass graduated cylinder that had been cut off to hold 1 ± 0.05 cc.

Preparatory to using the exotic pollen technique for determination of absolute pollen frequency (Matthews, 1969; see also Bonny, 1972, and Peck, 1974), residues were washed several times with water and were put into 95% ethyl alcohol. One-half or one cc. of an exotic pollen mixture was added to each residue. The exotic marker, *Zamia floridana* pollen suspended in pure glycerine, was mixed on a magnetic stirrer for at least one hour to insure homogeneity before adding it to a sample. The concentration of pollen in the suspension was determined to be $7.49 \pm 0.18 \times 10^4$ grains/cc. through a series of counts using an AO Spencer hemacytometer. One hundred counts were needed to determine the mean number of grains with a confidence level of 95% using the formula given by Bonny (1972). As suggested by Bonny (1972), the marker was added at the end of sample treatment. This is useful, because contaminants on the *Zamia* strobilus or those introduced during procedures used to extract pollen from it remain unacetolyzed and are therefore identifiable.

Residues were mounted in silicone oil (12,500 c.s.) after being suspended in tertiary butyl alcohol (TBA). Slides were heated on a warming tray (75°C) to promote evaporation of the TBA, and residues were mixed with silicone oil using a clean dissecting needle. Cover slips were sealed with nail polish once the silicone oil had spread out evenly underneath.

Only slides with a uniform distribution of pollen were used for the counts. To check if the distribution of grains was random, the slides were examined visually. Also, as suggested by Peck (1974), a Chi square test based on observed and expected frequencies of grains in successive traverses was used. Slides for which the χ^2 values were significant ($P < 0.05$) were rejected.

Three hundred arboreal pollen grains were counted at nearly all sampling depths. Counting was done at a magnification of 250×, and more difficult determinations were made at a magnification of 1000× with the use of an apochromatic oil immersion lens. Identification of pollen was aided by a small but adequate reference collection. Spear counted most samples, except for seven levels in Zone T which were tallied by Miller.

The sum was calculated by totalling the number of pollen of trees and nonarboreal plants excluding spores, pollen of bog species and other aquatics, broken pine and spruce grains, and indeterminable, badly cor-

roded or crumpled, and unknown grains. Calculation of the relative frequency of the excluded categories was done separately from the arboreal and nonarboreal pollen by using the total number of all pollen and spores in a count as the percentage base.

Absolute pollen frequency was calculated using the following formula:

$$(\text{Number of exotic pollen grains added}) \left(\frac{\text{count of fossil grains}}{\text{count of exotic grains}} \right)$$

The absolute frequency of each pollen or spore type in a count was calculated by a similar proportion. Pollen influx values, i.e. the number of grains deposited/cm.^{2}/year, were determined by dividing the absolute frequency by the number of years it took one cm. of sediment to accumulate.

Per cent organic matter in the sediment (see FIGURE 2) was measured by determining the weight of 1 cc. samples after they dried for 24 hours (at 105°C) and the weight of the ash after the samples burned for 1 hour in a muffle furnace (at 550°C). The difference between the two figures divided by the dry weight value and multiplied by 100 gives the per cent weight loss on ignition.

GENESEE VALLEY PEAT WORKS. Methods used to prepare the relative frequency pollen diagram for this site and to produce the absolute pollen frequency data, which were obtained by a somewhat different volumetric technique than that described above, are given by Miller (1973).

RESULTS

POLLEN DIAGRAMS

The Belmont Bog pollen profile (FIGURE 2) has been divided into Zones T, A, B, C-1, C-2, C-3a, and C-3b to facilitate comparison with profiles from nearby regions. Percentages of pollen types not included on the pollen diagram are given in APPENDIX C.

ZONE T (7.1–4.7 m.). Zone T consists of pollen deposited in the lower 2.4 m. of clay and shows little internal differentiation. The zone is characterized by abundant nonarboreal pollen (NAP), which varies from a high of about 70% (6.1 m.) to a low of about 50% at the end of the zone. Spectra at 5.8 and 7.1 m., containing 49 and 63% NAP respectively, were contaminated with pollen from younger sediment, presumably as the unprotected auger was pulled to the surface. Hemlock pollen accounts for 1.3% of the sum at 5.8 m., but it does not occur at sampled levels immediately above or below. At 7.1 m. only a few hemlock pollen grains were found. Additional samples were counted at 6 and 6.8 m., and although these agree well with other Zone T pollen assemblages, they were rejected because of more abundant contaminants.

The relative frequency pollen diagram (FIGURE 2) gives percentages

of major pollen types in Zone T. Cyperaceae and Gramineae are the principal NAP components. From 55 to 32% of the pollen total was contributed by members of these families. There is a general reduction upward in the amount of Cyperaceae pollen present, but the representation of Gramineae is more or less constant throughout the zone. Percentages of *Alnus* and *Salix* are also fairly constant (ca. 3–4% each). Both *Artemisia* and high-spine Compositae are somewhat better represented above 5.6 m. Pollen of *Thalictrum* is present throughout, and maximum percentages occur near the beginning and end of the zone.

The two principal arboreal pollen (AP) components are *Picea* and *Pinus*. The percentage of *Picea* pollen increases from 13% (7.1 m.) to 22% (4.8 m.). Three categories of pine pollen are shown on the diagram. The only regional species of *Pinus* subg. STROBUS is *Pinus Strobus*, and no pollen of this species was found between 7.1 and 5.6 m. except for a few grains probably present as contaminants. The body width of most pollen in the *Pinus* undifferentiated category (those grains in which the germinal furrow was obscured by grain orientation, folding, or breaking) and in the *Pinus* subg. PINUS category measure 35–40 μm. Since *Pinus Banksiana* has been found to be about this size (Whitehead, 1964), it probably is the dominant pine represented in Zone T sediments. Total *Pinus* pollen generally accounts for 16 or 17% of sums between 7.1 and 5.5 m., but from 5.5 to 4.7 m., pine comprises 10 to 13% of the total.

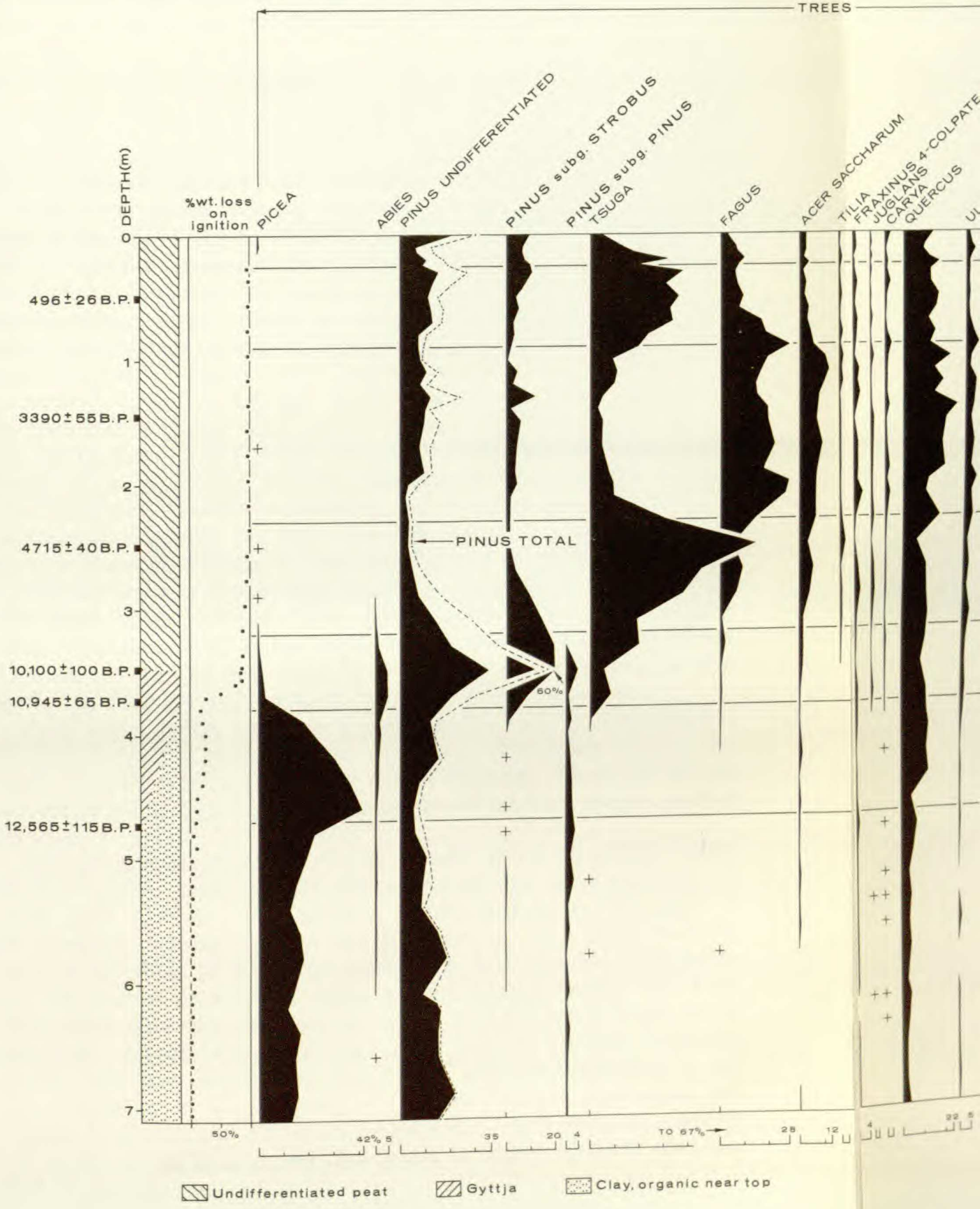
Low percentages of pollen from *Acer*, *Fraxinus* (4-colpate grains), *Carya*, and *Ulmus* occur sporadically throughout Zone T. Somewhat more frequent is pollen from *Quercus*, *Fraxinus* (3-colpate grains), *Betula*, and *Carpinus* or *Ostrya*.

Since the number of grains/cc. shows little variation in Zone T (FIGURE 3A), the sedimentation rate (0.062 cm./year) was probably constant during accumulation of sediments assigned to this zone (FIGURE 3C). The rate is in the same order of magnitude as that calculated for Rogers Lake, Connecticut (Davis, 1967b), but the rate at Rogers Lake is about 1.7 times greater. Total pollen influx was about 1200 grains/cm.^{2}/yr. at the base of Zone T at Belmont Bog. Above 6.2 m., pollen influx gradually increases until a maximum of 3000 grains is reached at the top of the zone. A fairly sharp change in influx (1600 to 2600 grains) occurs between 5.8 and 5.4 m.

The pollen influx diagram (FIGURE 4) yields some important additional details. Influx of Cyperaceae pollen (ca. 500 grains/cm.^{2}/yr.) remains more or less constant throughout the zone except for higher values between 5.2 and 5.4 m. Influx of Gramineae, which is about 50 grains at 7.1 m., increases gradually to 200 grains at 5.6 m. and to 350 grains at 4.8 m. Influx of *Picea* pollen is low (ca. 150 grains) until about 5.8 m. Above this level, influx increases to about 800 grains (4.7 m.). The magnitude of pine pollen influx is similar to spruce until about 5.8 m.; how-

FIGURE 2. Relative pollen frequency diagram for Belmont Bog, Allegany County, New York.

BELMONT BOG, ALLEGANY COUNTY, NEW YORK: RELATIVE POLLEN FREQUENCY



BELMONT BOG, ALLEGANY COUNTY, NEW YORK: RELATIVE POLLEN FREQUENCY

ever, pine influx never exceeds 300 grains/cm.²/yr. in the upper portion of Zone T. Total influx of pollen from deciduous trees is never more than 250 grains at any one level throughout Zone T.

ZONE A (4.7–3.8 m.). Abundant *Picea* pollen occurring in 0.9 m. of clay is found in Zone A. The T/A boundary has been placed at 4.7 m., and this level (4.7–4.75 m.) was dated at 12,565 ± 115 yrs. B.P. Spruce pollen increases from 22% (4.8 m.) to a maximum of 42% (4.6 m.) early in Zone A, then gradually decreases to 18% at the top of the zone.

Total *Pinus* pollen increases from 8% at the bottom of the zone to 23% at the top. Pollen of *Pinus Strobus* does not begin to increase until 3.9 m. Because measured pine pollen below 3.9 m. are small, *Pinus Banksiana* is probably the dominant pine represented below this level. Besides *Pinus Strobus*, pollen of *Abies*, *Tsuga*, *Fagus*, *Fraxinus* (4-colpate), and *Platanus* increase in frequency between 4 m. and the end of the zone. *Fraxinus* (3-colpate) and *Carpinus-Ostrya* increase to 5 and 7.5% respectively upward in the zone. Several tree pollen types listed above can be identified to species, since one or in some cases two species occur in the northeastern United States. They are *Abies balsamea*, *Tsuga canadensis*, *Fagus grandifolia*, *Fraxinus americana* or *F. pennsylvanica* (*Fraxinus* 4-colpate), *Platanus occidentalis*, and *Fraxinus nigra*. Pollen of *F. quadrangulata* usually has three colpi like that of *F. nigra*, but because of its southern distribution, *F. quadrangulata* can be eliminated.

NAP percentages remain high (25–35%) in Zone A. Upward in the zone sedge pollen decreases from 10%. Representation of grass pollen varies from about 10% at the bottom of the zone to 5% at 4 m. to over 12% at 3.9 m. The only other herb pollen in any abundance is from species of *Ambrosia* and *Artemisia* and from other Compositae.

Total pollen influx, based on a sedimentation rate of 0.062 cm./yr., increases from 3000 grains/cm.²/yr. (4.6 m.) to 4400 grains (3.9 m.) and finally to over 6000 grains at the top of the zone. Above 3.9 m. the amount of pollen from *Pinus Strobus* and deciduous trees shows a marked increase.

The pollen influx diagram (FIGURE 4) adds additional details. Influx of *Picea* pollen increases from 800 grains/cm.²/yr. to a maximum of 1400 grains (4.4 m.), after which it steadily declines to 300 grains at the boundary between Zones A and B. Influx of *Abies* pollen increases from < 50 grains (4 m.) to 200 grains (3.8 m.). Pine has a low influx (< 450 grains) until 3.9 m., where a sharp increase begins. At 3.8 m. 2000 grains were deposited/cm.²/yr., and a further increase occurs above this level. Between 4.6 and 4.4 m., influx rates for *Quercus*, *Carpinus-Ostrya*, and *Salix* double, and these higher rates are maintained to the top of Zone A. At the beginning of the zone influx of Cyperaceae and Gramineae is 300 and 225 grains respectively. Both drop to a low of 120 grains within Zone A and then return to higher values at the zone A/B boundary.

ZONE B (3.8–3.2 m.). Assemblages of pine pollen characteristic of Zone B were deposited in three different types of sediment. The bottom 0.075 m. of sediment is clay. The transition from clay to gyttja occurs between 3.75 and 3.7 m. and is dated at 10,945 ± 65 yrs. B.P. (H: 4125–3279). A thin layer of gyttja (0.25 m.) accumulated over a period of about 850 years, after which the sediment changed to peat. The gyttja/peat transition (3.50–3.45 m.) has been dated at 10,100 ± 100 yrs. B.P. (H: 4125–3278). The remainder of Zone B sediment is peat.

In the relative frequency pollen diagram (FIGURE 2) all three *Pinus* curves show maximum percentages at 3.5 m. At this depth total *Pinus* is nearly 60% of the percentage base. *Pinus Strobus* accounts for at least one-third of this total and perhaps more, since some of the grains in the *Pinus* undifferentiated category are probably *Pinus Strobus*. However, the small size of many grains in *Pinus* subg. PINUS and *Pinus* undifferentiated categories indicate that *Pinus Banksiana* was also present. Spruce pollen decreases from 7% at the base of the zone to 1% at 3.5 m. and completely disappears near the B/C-1 boundary. *Abies* increases to 5% near the base of the zone and declines to 1% at the transition to Zone C-1. Percentages of deciduous tree pollen remain more or less constant during Zone B.

Between 10 and 25% of Zone B pollen sums are in the NAP category. *Alnus*, which accounts for most of the NAP, increases from 0% (at 3.8 m.) to 12.5% at 3.2 m. Cyperaceae decline from 7% (at 3.8 m.) to 2% at 3.5 m., a value that is maintained for the rest of the zone. Pollen of *Salix*, Gramineae, *Artemisia*, and various other Compositae has nearly disappeared by the middle of Zone B. Pollen of aquatic or semiaquatic plants such as *Potentilla palustris*, *Potamogeton*, *Myriophyllum*, and *Sagittaria* disappear above 3.6 m., while bog inhabitors (Ericaceae, *Nemopanthus*, and *Sarracenia*) are first detected between 3.5 and 3.3 m. Spores of species in the Polypodiaceae, Osmundaceae, and *Sphagnum* increase from < 1% to about 5%.

The number of grains/cc. (FIGURE 3A) increases by a factor of 10 from 7×10^4 to 7×10^5 (3.8–3.5 m.) and then decreases to 4.3×10^5 (3.3 m.). The sedimentation rate (see FIGURE 3C) changes three times in the zone. The deposition rate of clay is assumed to be the same as in Zones T and A. With the use of the radiocarbon dates that bracket the thin layer of gyttja, its sedimentation rate was calculated to be 0.03 cm./yr. Above 3.45 m., too few radiocarbon dates were obtained to accurately calculate a deposition rate for the peat. Hence, the pollen influx diagram (FIGURE 4) ends at 3.5 m. From 3.8 to 3.5 m., *Picea* influx decreases from 300 to 200 grains/cm.^{2}/yr. Pollen influx of both *Abies* and *Pinus* increases, *Abies* from 200 to 750 grains and *Pinus* from 2000 to 9600 grains. Influx values for *Quercus*, *Betula*, and *Alnus* also increase, while values for *Fraxinus* (3-colpate), *Carpinus-Ostrya*, Cyperaceae, and Gramineae either decline or remain constant.

For the upper 3.3 m. of sediment, an absolute frequency diagram (grains/cc.) was prepared. Although absolute pollen diagrams do not

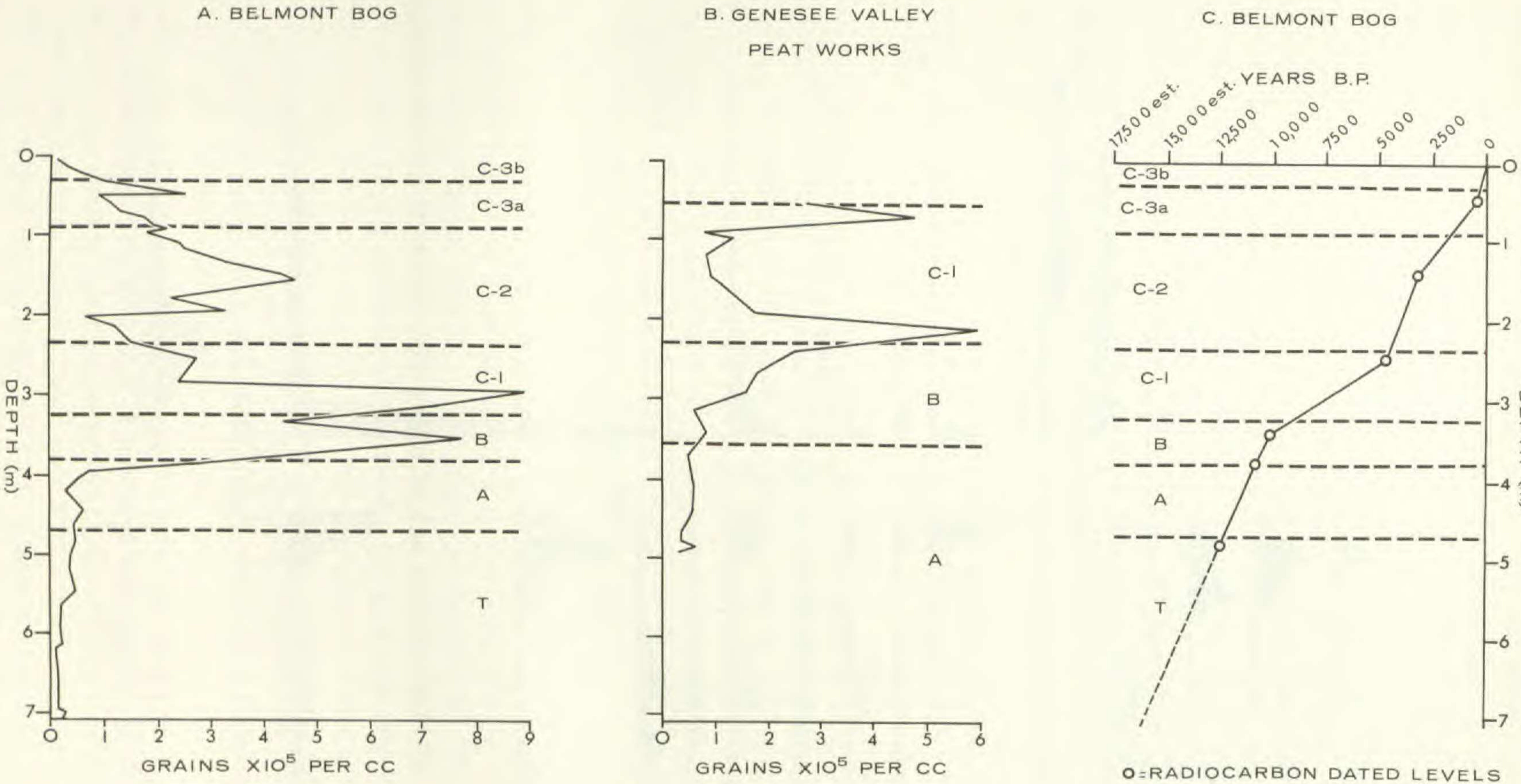


FIGURE 3. **Graphs:** A, absolute pollen frequency (grains/cc.) at Belmont Bog; B, same variable at Genesee Valley Peat Works; C, depth *versus* radiocarbon age of dated sediment samples (the sedimentation rate is the slope of the curve).

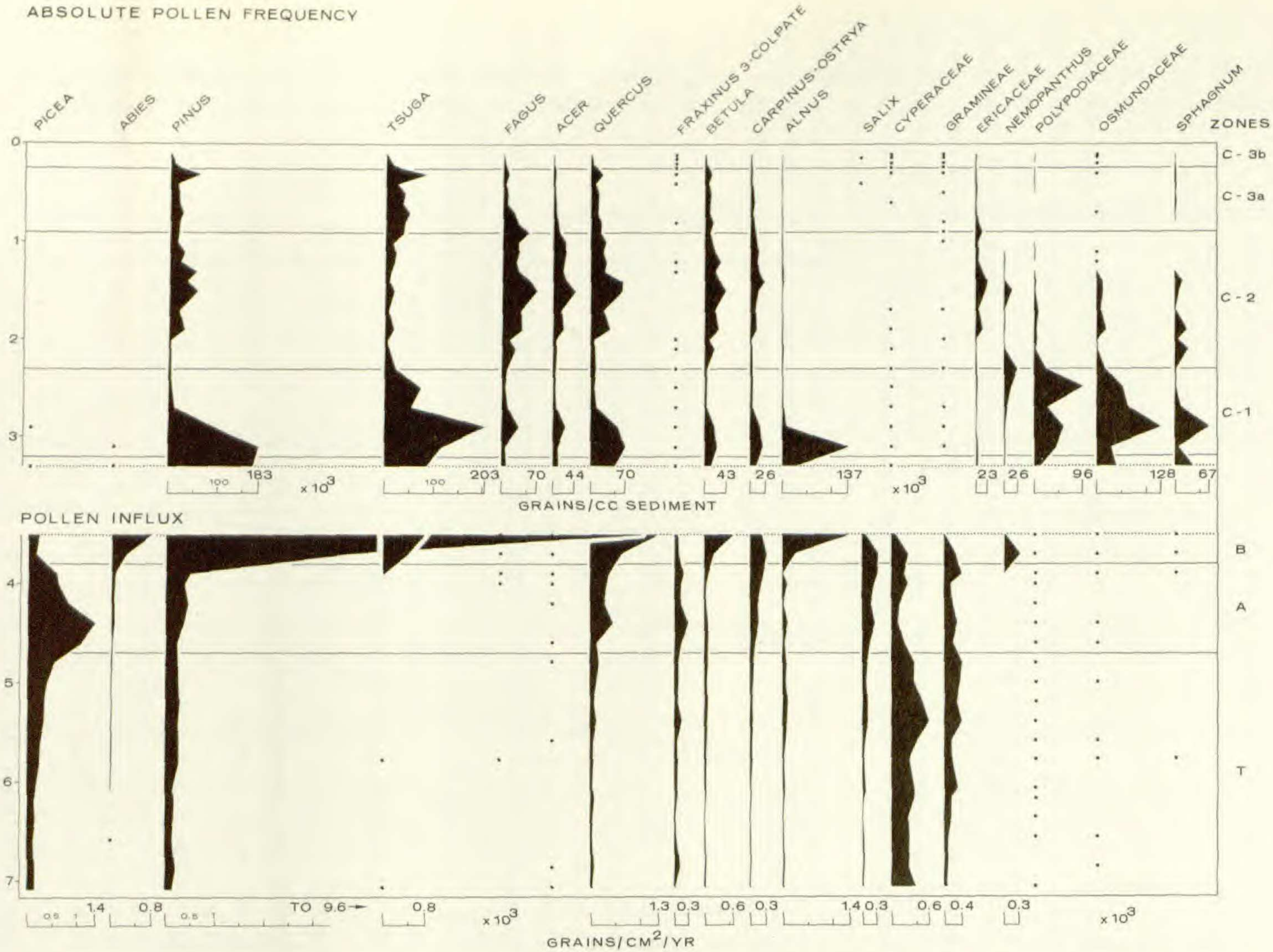


FIGURE 4. Diagrams of absolute pollen frequency (upper half) and pollen influx (lower half) at Belmont Bog.

eliminate the influence of sedimentation rate on pollen concentration, they allow the problem of interdependence of percentages to be bypassed. Too little of Zone B is shown on the absolute pollen diagram (FIGURE 4) to warrant discussion at this point.

ZONE C-1 (3.2–2.3 m.). High relative numbers of *Tsuga* pollen characterize Zone C-1, which is recorded in 0.9 m. of peat. The boundary between Zones B and C-1 (3.2 m.) was placed at the middle of the *Pinus* decline and the *Tsuga* rise. Total pine pollen decreases from 34 to < 5% upward in the zone. On the basis of size measurements and morphology, most pine pollen was contributed by *Pinus Strobus*. No pollen assignable to the *Pinus* subg. PINUS category occurs in Zone C-1, although *P. resinosa* pollen is possibly a significant proportion of the *Pinus* undifferentiated category. Hemlock pollen increases from 17% to a peak of > 65% at 2.5 m. Sediment between 2.47 and 2.52 m. was dated at 4715 ± 40 yrs. B.P. (H: 4124–3296).

Pollen of *Fagus, Acer,* and *Betula* increase slightly in percentage, while representation of other trees remains constant. The total percentage of NAP is low (< 5%) throughout the zone, except at 3.1 m., where abundant *Alnus* pollen was recorded. Pollen and spores from known and presumed bog species fluctuate greatly in the zone. Spores of *Sphagnum* reach a maximum of 8% at 2.9 m. and gradually decrease upward. Osmundaceae rise from 5% (at 3.2 m.) to 25% at 2.7 m. and decline to 10% at the top of Zone C-1. Spores of members of the Polypodiaceae reach a maximum of > 30% at 2.5 m. *Nemopanthus* pollen, which was < 1% at 2.8 m., attains a maximum of 17% at the C-1/C-2 boundary.

The absolute number of grains/cc. (FIGURE 3A) reaches 8.9×10^5 at 2.9 m., then declines to 1.5×10^5 at the end of the zone. The absolute frequency diagram (FIGURE 4) shows some interesting trends. *Tsuga* pollen concentration increases upward in the zone, and at 2.5 m. its maximum concentration occurs. Maximum percentages of *Tsuga* also occur at this depth. However, the extent of the increase may be diminished by an increase in the sedimentation rate at the C-1/C-2 transition (see FIGURE 3C). Above 2.5 m., the absolute number of *Tsuga* pollen decreases. Spores from members of the Osmundaceae reach a maximum value at 2.9 m. and become gradually less abundant upward in Zone C-1. Both *Nemopanthus* and Polypodiaceae reach maximum numbers in the last 0.2 m. of Zone C-1 sediment.

ZONE C-2 (2.3–0.9 m.). The most significant event in Zone C-2 is the *Tsuga* decline. The C-1/C-2 boundary was placed at 2.3 m. halfway through the abrupt decrease in percentages of *Tsuga* pollen (FIGURE 2). *Tsuga* percentages remain low (< 10%) until the end of Zone C-2 (0.9 m.), where an increase to 20% occurs. Near the center of Zone C-2, sediment was dated at 3390 ± 55 yrs. B.P. (H: 4123–3277). During the interval of lowest *Tsuga* frequency (2.1–1 m.), percentages of *Pinus, Fagus, Acer, Quercus,* and *Betula* increase. NAP percentages re-

main low throughout the zone ($< 5\%$). Percentages of pollen and spores of bog species vary considerably within the zone. Significant amounts of Ericaceae (ca. 5%) are first detected at 1.9 m. At the base of Zone C-2 *Nemopanthus* has reached 17% of the sum; however, it becomes greatly diminished upward. Both Polypodiaceae and Osmundaceae decline from high values at the beginning of the zone and then disappear near its end. *Sphagnum* increases from $< 5\%$ (2.3 m.) to 20% (2.1 m.), but it also disappears near the end of the zone. The absolute pollen diagram shows that the number of grains/cc. of *Pinus*, *Fagus*, *Acer*, *Quercus*, *Betula*, and *Carpinus-Ostrya* increase and exceed the number of grains/cc. of *Tsuga* throughout most of the zone.

ZONE C-3a (0.9–0.25 m.). Increased percentages of *Tsuga* pollen characterize Zone C-3a. The C-2/C-3a transition was placed at 0.9 m. near the midpoint of *Tsuga* increase. Within the zone *Tsuga* reaches a maximum of 37% near the C-3a/C-3b boundary. Total *Pinus* pollen increases gradually from 10% to 25%. *Fagus* decreases from 27% to 7% in the same interval. Percentages of *Acer* decrease slightly.

The number of grains/cc. undergoes considerable change (FIGURE 3A), varying from 2.2×10^5 grains (0.9 m.) to 1.0×10^5 (0.4 m.) to 2.5×10^5 grains (0.30 m.). The number of *Tsuga* grains/cc. increases from 1.2×10^4 (1 m.) to 4.6×10^4 (0.9 m.) and to 8.0×10^4 near the top of the zone. As in the relative frequency diagram, the absolute number of *Fagus* and *Acer* pollen decreases. Sediments between 0.47 and 0.42 m. gave a radiocarbon age of 496 ± 26 yrs. B.P. (H: 4122–3286).

ZONE C-3b (0.3–0 m.). This, the topmost zone of the profile, is characterized by high values for NAP categories, especially Gramineae and *Ambrosia*. Upward in the zone, Gramineae increases from 5% to 10%. In the same interval *Ambrosia* increases from about 2.5% (0.25 m.) to 25% (0.1 m.), although only 13% *Ambrosia* pollen occurs in the surface sample. A reduction of *Tsuga* representation from about 25% to 2% occurs upward in the zone. Percentages of *Fagus* and *Betula* also decline. After initial lows, *Pinus*, *Acer*, and *Quercus* show increases above 0.1 m. Two groups of bog plants markedly increase in Zone C-3b, Ericaceae from 2% (0.3 m.) to 18% (surface) and *Sphagnum* to 22% above 0.1 m.

The number of grains/cc. (FIGURE 3A) decreases from 2.5×10^5 to 2.0×10^4 upward in the zone. The absolute pollen diagram (FIGURE 4) shows decreases for all categories recognized.

SURFACE SAMPLES

To facilitate interpretation of the fossil pollen spectra, particularly Zone C assemblages, surface samples were collected from several mature, undisturbed forest stands. Three samples obtained from sites in northwestern Pennsylvania (Cook Forest, Hearts Content, and Tionesta Scenic Area) are graphed in FIGURE 5 (see also APPENDIX D). Surface and presettlement (0.3 m.) spectra from Belmont Bog are included for com-

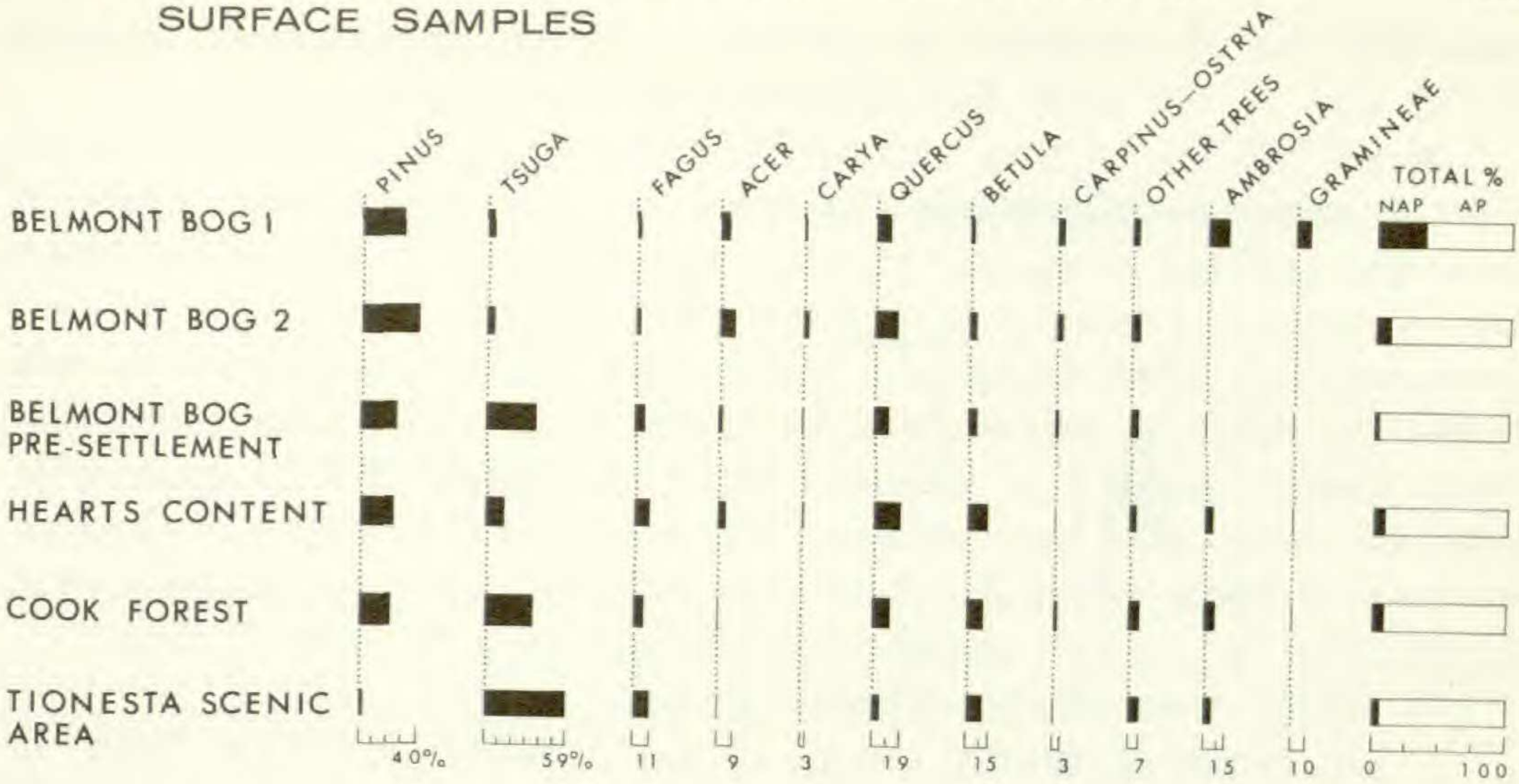


FIGURE 5. Surface pollen assemblages from sites in west-central New York State and northwestern Pennsylvania. Percentage base for Belmont Bog 1 included agricultural indicators; for Belmont Bog 2, agricultural indicators were excluded from the percentage base.

parison. The surface sample from the bog has been calculated both including (Belmont Bog 1) and excluding (Belmont Bog 2) agricultural indicators (*Ambrosia*, Chenopodiaceae-Amaranthaceae, Gramineae, *Plantago*). The most important trees in these samples are *Pinus*, *Tsuga*, *Quercus*, and *Betula*. NAP values are generally low ($< 10\%$), except for the Belmont Bog surface sample.

INTERPRETATION AND DISCUSSION

VEGETATION RECONSTRUCTION

ZONE T (16,400[2] to 12,500 yrs. B.P.). Zone T spans a period of 3900 years and is characterized by high percentages of pollen of herbs. The pollen assemblages represent an open, tundralike vegetation, but the exact nature of this vegetation, particularly the density of trees (if indeed any occurred near the depositional basin), is uncertain. Zone T pollen assemblages from Belmont Bog are in general similar to equivalent spectra at other sites in glaciated North America (Davis, 1967a), except that in the Midwest more spruce and less pine occurs, while in New England the reverse is true. Belmont Bog spectra are intermediate in this regard. Even though Zone T at Belmont Bog spans a much longer interval of time, its floristic composition is almost identical to Zone T at Allenberg Bog (Miller, 1973), which is 80 km. to the west in New York State. Zone T pollen assemblages at these sites compare well with surface pollen accumulations from the boreal forest-tundra ecotone at Fort Churchill, Manitoba (Ritchie & Lichti-Federovich, 1967). Also similar are spectra from a site 350 km. to the south in Maryland which

[2] This date is estimated assuming constant sedimentation rate (see FIGURE 3C). Estimated dates are marked with an asterisk.

show that tundra extended far southward in the Appalachians between 18,500 and 12,600 years ago (Maxwell & Davis, 1972).

Division of Zone T into two parts, one interpreted as treeless tundra with an extreme climate and the other as park-tundra with scattered trees and perhaps a warmer climate, is indicated by the pollen influx data. Between 7.1 and 5.8 m. (16,400*–14,200* yrs. B.P.), 1200 to 1600 grains/cm.^{2}/yr. were deposited. Pollen influx of this magnitude is well within the range of values given by Davis *et al.* (1973) for tundra regions. Sedges account for almost half of the influx (500 grains/cm.^{2}); *Picea* and *Pinus* each have values of 150 grains, and 50 grains of *Quercus* occur. Low influx values for these trees indicate that they probably were absent from the region around Belmont Bog early in Zone T time.

The upper park-tundra subzone (5.8–4.7 m.; 14,200*–12,500 yrs. B.P.) was deposited during retreat of ice from western New York, in particular during withdrawal from the Lake Escarpment/Valley Heads and younger moraines (see dates in Calkin, 1970). In the upper part of Zone T, pollen influx increases from 1600 to 3000 grains/cm.^{2}/yr. These values fit those available for forest-tundra vegetation with sparse stands of *Picea glauca* and *P. mariana* (Ritchie & Lichti-Federovich, 1967). Influx values for Cyperaceae and Gramineae increase slightly, and at other sites this increase in pollen production has been accounted for by a warming climate or by the increased protection offered by trees (Davis, 1969b). Influx values for *Pinus* and *Quercus* remain more or less constant in the upper part of Zone T, indicating that they were probably still absent from surfaces near the site. In contrast, influx values for spruce rise from 300 to 850 grains upward in the zone, meaning that spruce had become established in scattered stands near the basin late in Zone T time. During this period spruce seems to have migrated closer to the basin at a rate much faster than that of either pine or oak.

Based on the relative frequency diagram, Zone T at Belmont Bog shows little internal differentiation. No major fluctuations of pollen percentages are present which can be correlated conclusively with oscillations of ice fronts to the north. There is no evidence of any change in climate during the period in which Zone T sediments accumulated except for gradual warming between 16,400* and 12,500 yrs. B.P. These results support Davis and Deevey's contention (1964) that percentage fluctuations of pollen present in southern New England in zones comparable to Zone T in western New York have little relationship to vegetation change, since they involve small absolute numbers of grains. The results also agree with prespruce zone pollen profiles in Minnesota (Cushing, 1967), where no vegetation changes have been found to correlate with fluctuations of ice lobes.

ZONE A (12,500 to 11,000 yrs. B.P.). During the 1500 years represented by Zone A, vegetation adjacent to the Belmont Bog depositional basin was probably open spruce woodland. There are several pieces of evidence indicating that the vegetation was open rather than closed spruce

FIGURE 6. Relative pollen frequency diagram from Genesee Valley Peat Works, Allegany County, New York (modified somewhat from Miller, 1973).

forest. Percentages of spruce pollen in the zone are low (42% of the pollen sum), and NAP percentages are unusually high (25–30%). In addition, certain nonarboreal plants represented in the zone, such as *Salix* (which reaches maximum values in Zone A), *Epilobium*, *Campanula*, *Ambrosia*, Chenopodiaceae or Amaranthaceae, Caryophyllaceae, *Thalictrum*, and *Artemisia*, have high light requirements. Influx values for Gramineae and Cyperaceae are maintained at significant levels (ca. 300 grains/cm.^{2}/yr.) but are slightly reduced from values in Zone T. Total pollen influx for Zone A spectra (3000 to 6000 grains) compares well with the range of values given in Davis *et al.* (1973) for spruce woodland.

A comparable zone of low spruce and relatively high NAP percentages was found at the nearby Genesee Valley Peat Works (FIGURE 6). Miller (1973) had difficulty interpreting this zone and suggested two alternatives. One was that spruce forest existed in the uplands around the site and species contributing NAP occurred in marshes on poorly drained surfaces adjacent to the basin. If this situation prevailed, less NAP should be present at Belmont Bog, where the surrounding slopes are steep. Sampling sites close to each other but at a critical distance help separate local and regional components of the pollen rain (Turner, 1970; Brubaker, 1973), and since Zone A sediments at both sites have high percentages of NAP, local influences appear to be ruled out. Consequently, the second alternative, sparse spruce woodland, is supported by data from Belmont Bog.

Spruce is the most abundant pollen type found in Zone A. Forty-two per cent *Picea* pollen is present near the bottom of the zone, and maximum influx values (1350 grains/cm.^{2}/yr.) also occur at this level. Therefore, *Picea* should have reached its maximum density in the vegetation early in Zone A, just above sediments radiocarbon dated at 12,565 yrs. B.P. Sediments from 4.4 to 3.8 m. record a steady decline in *Picea* influx and slight increases in influx of other species. Although only the number of grains/cc. was determined for sediments from the Genesee Valley Peat Works (FIGURE 3B), these data agree closely with determinations of the same variable at Belmont Bog (FIGURE 3A). Total pollen concentration in Zone A ranges from 4.2 to 8.5 $\times$ 10^4 grains/cc. at the Peat Works and from 4.5 to 7.1 $\times$ 10^4 at Belmont Bog. The maximum number of spruce pollen/cc. at both sites is nearly the same (16,000 at the Peat Works *versus* 22,000 at Belmont Bog), and these values are reached at equivalent levels. Similar maximum concentrations of Cyperaceae pollen occur at the Peat Works (17,400) and Belmont Bog (17,200). The general correspondence of the absolute pollen data indicates regional continuity in the vegetation during Zone A time.

Influx of pine pollen remains low (ca. 400 grains) until 3.9 m. Without macrofossils it is impossible to determine if either *Pinus Banksiana* or *P. resinosa* was present or when in Zone A time pine reached the region near the depositional basin. Indeed, both pines may have occurred, even though total pine influx values are low. These pines probably do

not produce as much pollen as *P. Strobus* (Davis *et al.*, 1973); therefore, the increase in influx above 3.9 m. may relate to an abrupt appearance of *P. Strobus* at this level. Alternatively, *P. Banksiana* and *P. resinosa* could have been absent or very sparsely represented in the region until later in Zone A time (above 3.9 m.) when they increased in abundance with *Pinus Strobus*.

Higher influx values for *Quercus*, *Fraxinus*, *Carpinus-Ostrya*, and *Salix* indicate that these species either migrated closer to the depositional basin or increased in abundance as *Picea* decreased.

ZONE A at Belmont Bog differs in some respects from other late-glacial profiles in eastern North America. The spruce (A) zone at Belmont is much shorter than those recorded at many New England and Midwest sites. The New England A zone has been subdivided into spruce-hardwood (12,000–10,500 yrs. B.P.) and spruce-fir (10,500–9500 yrs. B.P.) subzones. In the Great Lakes region the spruce zone can be split into spruce-hardwood (12,000–11,500 yrs. B.P.) and spruce-*Artemisia* (11,500 yrs. B.P.) subzones (Davis, 1967a). Belmont Bog has only a spruce-hardwood subzone. Spruce was abundant for only several hundred years, and it became of minor importance after 11,000 yrs. B.P. Zone A pollen assemblages at Belmont Bog compare better with similar spectra at localities south of the limit of glaciation. At sites on the New Jersey Coastal Plain, Sirkin *et al.* (1970) determined that a short spruce zone was rapidly replaced by one in which oak pollen was prominent. Martin (1958) noted the complete absence of a spruce zone in southeastern Pennsylvania and concluded that the climate went from one too cold to one too warm for spruce. In this region the vegetation changed directly from park-tundra to pine forest. Spruce-rich vegetation persisted for much less than 1500 years around the site of Belmont Bog.

The age determination at Belmont Bog for abrupt rise in spruce pollen influx, which marks the beginning of Zone A, corresponds closely with a previously reported date (12,730 ± 200 yrs. B.P.; Calkin & McAndrews, 1969) for the same event at a site in Erie County, New York, some 80 km. to the northwest.

ZONE B (11,000 to ca. 8500 yrs. B.P.). The interval of time spanned by Zone B has only been approximately dated. Sediments at the bottom of the zone are about 11,000 years old on the basis of a radiocarbon date of 10,945 yrs. B.P. at 3.7 m. No date is available for the top of the zone. However, an estimate based on the sedimentation rate (FIGURE 3C) puts it between 9000 and 8500 yrs. B.P. The zone is characterized by a pine maximum at 3.5 m. The total influx at this depth is 2.3×10^4 grains/cm.^{2}/yr., which is low compared with modern sites in pine forest in Michigan (Davis *et al.*, 1973). Influx of this magnitude is, however, within the known range of values, and the difference may relate to the morphology of the basin at Belmont Bog.

The pine maximum at Belmont is dated at 10,100 yrs. B.P. This is

about 1000 years earlier than the pine maximum at Protection Bog (Miller, 1973), which is 70 km. to the northwest, and at Crystal Lake, 200 km. to the southwest in Pennsylvania (Walker & Hartman, 1960). The absence of synchroneity between these dates could relate to occurrence during sedimentation of ^{14}C deficient carbonate from local bedrock or till. Carbonates from such sources in limnic sediments produce age determinations that are somewhat too old. The presence of fossils of the calcicolous moss *Meesia triquetra* at equivalent levels in the basin of the Genesee Valley Peat Works (Miller, 1973) indicates that pond waters at this site, and perhaps in the basin of Belmont Bog as well, were somewhat calcareous.

Zone B at the nearby Genesee Valley Peat Works (FIGURE 6) is broader than that at Belmont Bog. However, the same time interval is probably represented, and the narrower zone at Belmont may be the result of slower sediment accumulation. Some variation in Zone B between the two sites could also be from differences in the local pollen rain. One clear difference in local pollen rain is evident. Pollen of *Alnus* is very abundant in B and lower C-1 Zone sediments at Belmont Bog, but *Alnus* pollen does not occur in Zone B at the Peat Works.

It has been speculated that the abrupt decline in spruce and subsequent rise in pine recorded at many sites in the northeastern United States was due to climatic warming, which occurred about 10,000 years ago (Ogden, 1967). However, profiles from Belmont Bog and the Genesee Valley Peat Works show a gradual decline in spruce woodland during Zone A time. An increase in pine did not occur until *Pinus Strobus* reached the area 11,000 years ago, by which time spruce abundance was greatly diminished. Hemlock also appears to have migrated into or nearer the region of Belmont Bog at the same time.

Recent research on stable isotopes in Lake Erie sediments (Fritz *et al.*, 1975), combined with results from Belmont Bog, permits the following summary of late and early postglacial events. According to Fritz *et al.* (1975), there were two periods of climatic improvement, one from 13,000 to 12,000 yrs. B.P. and the other between 10,000 and 8000 yrs. B.P. Because of its location and long sedimentary record, vegetation recorded at Belmont Bog probably reflects both of these changes. The first climatic improvement can be correlated with the transition to spruce woodland. The date for this transition at Belmont Bog (12,500 yrs. B.P.) compares favorably with an inferred date for a rise in spruce recorded in sediments of Lake Erie. However, the gradual decline in spruce beginning near the base of Zone A is more difficult to explain. Perhaps the climate warmed too fast or surfaces became edaphically unsuited for spruce regeneration and persistence. Pines and/or hemlock could not immediately replace spruce, since they did not enter the area or expand until about 11,000 yrs. B.P.

An alternative explanation for the drop in spruce influx is climatic deterioration during Zone A time. Fritz *et al.* (1975) acknowledge that after an initial increase, temperatures could have slowly dropped again

as they did in Great Britain. Unfortunately, there is an hiatus in their record between 12,500 and 10,500 yrs. B.P. caused by low water levels in an ancestral stage of Lake Erie. If a drop in temperature did occur, the region of Belmont Bog might have been more sensitive to it than lowland sites to the north because of its relatively high elevation (497 m.).

The second climatic improvement recognized by Fritz *et al.* (1975), which occurred between 10,000 and 8000 yrs. B.P., can be correlated with events in the upper part of Zone B. Maximum total pine influx, which represents the maximum abundance of pine in the vegetation, is reached at 3.5 m. (10,100 yrs. B.P.). This is just before the warming interval occurred. After the climatic change, the environment became more favorable to the development of vegetation with abundant hemlock. Further research, including more radiocarbon dated profiles north and south of Belmont Bog, is needed before details of the shift from pine to hemlock domination can be established.

ZONE C-1 (8500 to 4400 yrs. B.P.). Forests dominated by *Tsuga canadensis* are recorded in the sediments of this zone. After 8500 yrs. B.P., the climate of western New York appears to have become more uniform, and vegetation changes appear synchronous. Miller (1973) has described the nature of this zone in detail, and results from Belmont Bog support his conclusions. A pollen assemblage (FIGURE 5) from a surface sample collected in the Tionesta Scenic Area, Allegheny National Forest (McKean County, Pennsylvania) matches well most Zone C-1 pollen spectra. This indicates close correspondence between the existing vegetation of the Tionesta area and that present during Zone C-1 time near Belmont Bog. The average basal area/acre of trees in the virgin forest along East Tionesta Creek (Hough, 1936) is about 140 ft.^{2}/acre, of which 63% is *Tsuga canadensis*, 20% is *Fagus grandifolia*, and 4% is *Acer saccharum*. The remaining 3% is *Acer rubrum*, *Betula lenta*, *Betula lutea*, and *Prunus serotina*. The two dominants, *Tsuga canadensis* and *Fagus grandifolia*, occur not only on middle and lower slopes but also on plateaus.

Events in the development of the peat deposit in the basin are recorded in sediments included in Zone C-1 and the transition to Zone C-2. Since only the lower portion of Zone C-1 occurs at the Genesee Valley Peat Works (FIGURE 6), the regional significance of events above this level can not be determined. It is interesting that just before the record ends at the Peat Works, maximum percentages of Osmundaceae occur. At a comparable level Belmont Bog has a similar peak of *Osmunda* spores, followed by peaks in curves for Polypodiaceae and *Nemopanthus* higher in Zone C-1. Pollen preserved in sediments recording the transition from Zone C-1 to Zone C-2 is badly corroded. Also, there is a high in the absolute pollen frequency curve (FIGURE 3A) near the transition. This evidence indicates that the water table of the bog may have dropped (as a response to drought?), allowing peat to become oxidized. As the mat dried out, ferns (Osmundaceae and Polypodiaceae) and shrubs (*Nemopanthus*) invaded it. These categories are also included in the absolute

pollen frequency diagram (FIGURE 4), which shows the magnitude of their representation at the C-1/C-2 transition. At the beginning of Zone C-2, return to a higher water table is indicated by increases in *Sphagnum* and *Typha* and a decrease in the absolute number of grains/cc., implying a faster sedimentation rate.

It is tempting to correlate this reconstruction of bog development with the abrupt decline of hemlock at about 4400 yrs. B.P. Miller (1973) suggested that the decline could be due to several years of severe drought. However, the drought may not have been intense and of short duration, but rather a gradual drying, as is indicated by the behavior of bog plants in the Belmont pollen record. Hemlock populations weakened by such droughts may also have been adversely affected by a normally innocuous biotic agent, such as some insect or fungus.

ZONE C-2 (ca. 4400 to ca. 1700 yrs. B.P.). Low percentages of hemlock pollen are recorded in the 2700 years represented by Zone C-2 at Belmont Bog. After the abrupt decline of hemlock, succession occurred, and *Fagus grandifolia*, *Betula*, *Acer saccharum*, and *Quercus* became more abundant. These results correlate well with those of Miller (1973) and indicate that postglacial vegetation change was synchronous in western New York.

ZONE C-3a (ca. 1700 to ca. 175 yrs. B.P.). Approximately 1700 years ago, hemlock began to regain its former dominance in the forest. The increase in *Tsuga* pollen is accompanied by decreases in percentages of *Fagus* and *Acer* pollen. The bottom of Zone C-3a is marked by a small but significant increase in *Castanea* pollen. *Castanea* increases in Zone C-3 at Rogers Lake, Connecticut (Davis, 1969a), but in western New York large percentages of chestnut pollen have been detected only at Allenberg Bog (Miller, 1973). In southwestern New York during Zone C-3a, the abundance of chestnut increased, probably on south-facing slopes, a preferred habitat in presettlement forests.

A modern analogue of vegetation recorded at Belmont Bog prior to settlement by European man is Cook Forest, a state park in Clarion County, Pennsylvania, about 30 km. south of the Tionesta Scenic Area. Most of the basal area at Cook Forest (62%) is even-aged white pine which began after fire 320 years ago. Only a few white pines older than this were found (Hough & Forbes, 1943). Hemlock accounts for 36% of the basal area (Morey, 1936). Forest surrounding Belmont Bog before settlement probably contained a similar stand of white pine.

ZONE C-3b (175 calendar yrs. B.P. to present). The upper 0.25 m. of peat contains postsettlement spectra. This zone is characterized by increased percentages of NAP taxa, particularly *Ambrosia* and Gramineae.

The resolution of the profile in Zone C-3b is not good enough to show clearly events of settlement. However, a few historical trends can be detected. The lumbering and clearing of land for agriculture caused a

sharp decline in AP percentages from 0.25 to 0.10 m. Above 0.1 m., percentages of *Tsuga*, *Fagus*, and *Betula* continue to decrease, while *Pinus*, *Acer*, and *Quercus* increase. This is possibly due to the cutting of second growth stands and virgin timber.

Increasing percentages of *Pinus*, *Acer* (mostly *Acer rubrum*), and *Quercus* are probably due to forest succession, which occurred as more farmland in the region was abandoned. A decrease in *Ambrosia* between 0.1 m. and the surface also indicates a decrease in open areas with abundant weeds and an associated increase in forested land.

Evidence for the great importance of hemlock in the Zone C-3 and C-1 forests is provided by the surface pollen assemblage. Although hemlock accounts for only 2% of total pollen in the surface sample, hemlock is the second most important species (after white pine) in the forest around the bog and the second most important species on the north-facing slope. Hemlock pollen is somewhat overrepresented in the pollen record (Davis & Goodlett, 1960; Miller, 1973), so perhaps sites used for vegetation analysis were atypical for the region which contributes pollen to the Belmont Bog sedimentary basin. Nevertheless, hemlock must have been much more abundant, possibly occurring in almost pure stands, around Belmont Bog in the past.

Age of the Olean Drift

The oldest radiocarbon age of sediment in the basin is 12,565 ± 115 yrs. B.P. With the use of this date and the date immediately above, both of which are of organic matter in clay, the sedimentation rate was calculated to be 0.062 cm./yr. It is probable that sediment below 4.75 m. accumulated at a similar rate, because pollen influx was more or less constant during Zone T. This assumption having been accepted, the deepest sediments are about 16,400 radiocarbon years old. Since most workers consider the Olean drift to have been deposited in the early or middle Wisconsinan, a date of 16,400 yrs. B.P. seems much too young.

The reason older sediments were not found in the Belmont Bog basin is uncertain. The basin may in fact not be on Olean till but on younger drift perhaps of Kent age (23,000–17,000 yrs. B.P.). Terminal moraines in southwestern New York are not like the well-defined moraines of the Midwest, and consequently Kent ice perhaps advanced farther than the position thought to mark its maximum extent. Although we have not attempted to trace the Kent terminal moraine, it occurs within 4.8 km. of the site (Muller, 1957), and an error in mapping would be relatively small.

A second possibility is that the basin is actually situated on drift of Olean age and the truncated record is due to failure to collect all the sediment. Since the basin is close to the Kent margin, coarse outwash could have been deposited in it. The auger used for sampling may have been stopped by cobbles of outwash sediment.

A third alternative is that the ice block left by Olean ice did not melt

immediately. The climate was perhaps so severe that melting did not start until the onset of warming associated with the Erie Interstade. Lake deposits in Minnesota show a lag between ice retreat and the beginning of deposition (Florin & Wright, 1969). Unlike Belmont Bog, however, such deposits characteristically have a layer of coarse plant debris directly above till and below lacustrine sediment. The organic debris represents material deposited on the surface of the buried ice block before it melted.

SUMMARY

1. Pollen recovered from a 7.1 m. sediment column from Belmont Bog shows regional changes in late-glacial and postglacial vegetation when compared with the pollen record from the nearby Genesee Valley Peat Works. These sites are located in the Allegheny Plateau section of southwestern New York State, 40 km. inside the southern limit of Wisconsinan glaciation. The depositional basin is on a surface generally considered to have been deposited by Olean ice. The age of the Olean drift is unknown but is thought to be early or middle Wisconsinan.

2. Before European settlement, much of the region around Belmont Bog was covered with Hemlock-white pine-northern hardwood forest, stands of which graded into Oak-chestnut forest that occupied dry, exposed, south-facing slopes. Today, nearly all of the forest has been cut over. Northern hardwood and Oak second-growth forests are found adjacent to the bog.

3. Seven zones (T, A, B, C-1, C-2, C-3a, C-3b) were recognized in the pollen record. The lowest, Zone T, represents about 3900 years of tundralike vegetation. Based on pollen influx data, the zone can be divided into two parts, treeless tundra with perhaps an extreme climate (16,400–14,200 yrs. B.P.) and park-tundra with a slightly warmer climate (14,200–12,500 yrs. B.P.).

4. The base of Zone A was dated at 12,565 $\pm$ 115 yrs. B.P., which correlates with a warming period proposed for that time by Fritz *et al.* (1975). Early in Zone A time, open spruce woodland surrounded the depositional basin. Spruce pollen, which was never too abundant (generally $< 30\%$), reached maximum values early in the zone. Percentages of NAP remained high throughout the interval, indicating that open conditions persisted.

5. The interval of time spanned by Zone B has not been determined directly. The bottom of the zone was dated 10,945 $\pm$ 65 yrs. B.P., and based on the sedimentation rate, Zone B ended an estimated 8500 radiocarbon years ago. The pine maximum was dated at 10,100 $\pm$ 100 yrs. B.P., which is approximately 1000 years earlier than the pine maximum at Protection Bog, a site 70 km. to the northwest. The second warming interval of Fritz *et al.* (1975) occurred during the upper part of Zone B and could account for the transition from a forest rich in pines to one with abundant hemlock.

6. Zones C-1, C-2, C-3a, and C-3b are similar to those previously described for sites in western New York. Surface samples from virgin forests in northwestern Pennsylvania match spectra in Zones C-1 and C-3a. Sediments just below the Zone C-1/C-2 transition (the hemlock decline) are 4715 ± 40 yrs. B.P. A date for the middle of Zone C-2 is 3390 ± 55 yrs. B.P. A date of 496 ± 26 yrs. B.P. from Zone C-3a was obtained at 0.47–0.52 m.

7. Assuming a fairly uniform sedimentation rate for the basal clay in the basin, the bottom of the deposit is estimated to be 16,400 years old. This is much younger than the previously inferred age of the Olean advance. Possible explanations for this discrepancy are (1) that the bog is not on Olean drift but on younger Kent till, (2) that deposition was delayed some thousands of years, or (3) that outwash from the Kent advance was deposited over pre-Kent sediment.

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APPENDIX A

Analyses of Vegetation Near Belmont Bog

Species	No.	Points of occurrence	Relative density	Relative frequency	Relative dominance	Importance value index
North-facing slope of Phillips Creek Valley						
Acer saccharum	25	13	20.8	15.8	21.5	58.1
Tsuga canadensis	25	11	20.8	13.6	19.5	53.9
Fraxinus americana	16	11	13.3	13.6	14.5	41.4
Acer rubrum	11	10	9.2	12.1	8.4	29.7
Fagus grandifolia	9	7	7.5	8.4	7.2	23.1
Quercus rubra var. *borealis*	7	6	5.8	7.3	8.5	21.6
Betula lutea	7	6	5.8	7.3	2.6	15.7
Carya ovata	5	5	4.2	6.2	4.3	14.7
Ostrya virginiana	5	5	4.2	6.2	2.0	12.4
Tilia americana	3	3	2.5	3.7	3.6	9.8
Prunus serotina	2	2	1.7	2.6	5.2	9.5
Pinus resinosa	3	1	2.5	1.1	1.0	4.6
Populus tremuloides	1	1	0.8	1.1	1.4	3.3
Carpinus caroliniana	1	1	0.8	1.1	0.3	2.2
South-facing slope of Phillips Creek Valley						
Quercus alba	33	17	27.5	22.6	34.0	84.1
Quercus rubra var. *borealis*	23	15	19.2	19.8	28.6	67.6
Acer saccharum	21	14	17.5	18.7	14.5	50.7
Fraxinus americana	16	12	13.3	15.9	8.9	38.1
Carya ovata	10	5	8.3	6.7	5.3	20.3
Populus tremuloides	6	4	5.0	5.2	3.1	13.1
Acer rubrum	3	3	2.5	4.0	1.4	7.9
Fagus grandifolia	4	2	3.3	2.4	2.0	7.7
Ostrya virginiana	2	2	1.7	2.4	0.9	5.0
Populus grandidentata	1	1	0.8	1.2	0.6	2.6
Tilia americana	1	1	0.8	1.2	0.5	2.5
Forest communities immediately adjacent to Belmont Bog						
Pinus Strobus	59	24	29.5	19.1	31.7	80.3
Tsuga canadensis	42	24	21.0	19.0	25.7	65.7
Acer rubrum	32	32	16.0	25.4	15.1	56.5
Acer saccharum	24	12	12.0	9.5	11.1	32.6
Prunus serotina	15	11	7.5	8.7	5.8	22.0
Fagus grandifolia	9	7	4.5	5.6	5.7	15.8
Betula lutea	6	4	3.0	3.2	0.9	7.1
Quercus rubra var. *borealis*	4	3	2.0	2.4	1.8	6.2
Amelanchier laevis	3	3	1.5	2.4	0.5	4.4
Populus tremuloides	2	2	1.0	1.6	0.8	3.4
Pinus resinosa	2	2	1.0	1.6	0.4	3.0
Ostrya virginiana	1	1	0.5	0.8	0.4	1.7
Betula lenta	1	1	0.5	0.8	0.2	1.5

APPENDIX B

Flora of Belmont Bog and Surrounding Area *

Bog Mat

Trees:
Pinus Strobus **

Shrubs:
Chamaedaphne calyculata
Pyrus floribunda

Herbs:
Eriophorum virginicum
Sarracenia purpurea
Vaccinium Oxycoccos

Bog Margin

Trees:
Amelanchier arborea
A. laevis

Shrubs:
Cornus racemosa
Ilex verticillata
Lonicera Morrowii
Nemopanthus mucronata
Rhododendron roseum
Vaccinium atrococcum
Vaccinium angustifolium var. *hypolasium*
Viburnum cassinoides
V. acerifolium

Herbs:
Calla palustris
Lemna minor
Osmunda cinnamomea **

Northern Hardwood

Trees:
Acer rubrum
A. saccharum **
Betula lenta
B. lutea
Fagus grandifolia **
Fraxinus americana
Ostrya virginiana
Prunus serotina
Quercus rubra var. *borealis*
Tsuga canadensis

Herbs:
Caltha palustris
Carex gracillima
Coptis groenlandica
Cornus canadensis
Dryopteris noveboracensis
D. spinulosa var. *intermedia*
Epifagus virginiana
Lycopodium annotinum
L. clavatum
L. complanatum var. *flabelliforme*
L. obscurum
Maianthemum canadense
Mitchella repens
Oxalis montana
Polygonatum pubescens
Trientalis borealis
Trillium grandiflorum
T. undulatum

Hemlock Unit

Trees:
Acer rubrum
Betula lutea
Fagus grandifolia **
Tsuga canadensis

Herbs:
Epifagus virginiana

White Pine Unit

Trees:
Acer rubrum

* Names after Fernald (1950).

** Voucher specimen unavailable; vouchers for other plants deposited in the University of North Carolina Herbarium (NCU).

Fraxinus pennsylvanica var. *subintegerrima*
Pinus Strobus **
Populus tremuloides
Prunus serotina
Quercus rubra var. *borealis*

SHRUBS:
Vaccinium myrtilloides

HERBS:
Clintonia borealis
Cypripedium acaule
Pteridium aquilinum var. *latiusculum*

Planted Species
Picea rubens
Pinus resinosa

APPENDIX C

PERCENTAGES OF POLLEN AND SPORES FROM BELMONT BOG SEDIMENTS NOT INCLUDED IN POLLEN DIAGRAM

Nyssa sylvatica: 0.2% (0 cm.), 0.8% (14 cm.), 0.3% (20 cm.), 0.3% (24 cm.), 0.3% (60 cm.), 1.5% (80 cm.), 1.0% (90 cm.), 0.9% (110 cm.), 0.6% (120 cm.), 0.9% (130 cm.), 0.6% (140 cm.), 0.9% (170 cm.), 0.3% (190 cm.), 1.6% (200 cm.), 0.3% (210 cm.), 0.6% (230 cm.), 0.3% (270 cm.), 0.6% (290 cm.).
Prunus serotina: 0.2% (0 cm.).
Liquidambar styraciflua: 0.3% (30 cm.), 0.3% (60 cm.), 0.3% (70 cm.), 0.3% (330 cm.).
Populus: 0.4% (0 cm.), 1.5% (10 cm.), 0.8% (14 cm.), 2.3% (20 cm.), 0.9% (40 cm.), 0.6% (70 cm.), 0.3% (80 cm.), 0.6% (90 cm.), 0.6% (110 cm.), 0.6% (120 cm.), 0.6% (140 cm.), 0.6% (170 cm.), 0.9% (190 cm.), 1.6% (200 cm.), 0.3% (210 cm.), 0.6% (230 cm.), 0.3% (270 cm.), 0.2% (370 cm.).
Celtis: 0.2% (400 cm.), 0.2% (460 cm.).
Morus: 0.2% (0 cm.).
Corylus: 0.4% (10 cm.), 0.4% (14 cm.), 0.3% (24 cm.), 0.3% (50 cm.), 0.3% (60 cm.), 0.3% (70 cm.), 0.3% (120 cm.), 0.6% (130 cm.), 1.2% (170 cm.), 0.6% (190 cm.), 0.3% (200 cm.), 0.3% (210 cm.), 0.6% (270 cm.), 0.9% (330 cm.), 0.5% (350 cm.), 0.5% (370 cm.), 0.8% (390 cm.), 0.4% (400 cm.), 0.5% (420 cm.), 0.2% (440 cm.), 0.6% (460 cm.), 0.2% (480 cm.), 0.2% (500 cm.), 0.6% (540 cm.), 0.2% (560 cm.), 0.8% (580 cm.), 0.2% (620 cm.).
Myrica: 0.3% (60 cm.), 0.3% (70 cm.), 1.9% (150 cm.), 0.4% (390 cm.), 0.2% (400 cm.), 0.2% (710 cm.).
Cephalanthus occidentalis: 7.4% (0 cm.), 0.4% (14 cm.), 0.3% (290 cm.), 0.2% (370 cm.).
* *Ilex*: 0.2% (480 cm.).
Rhamnus: 0.3% (140 cm.).
Viburnum: 0.3% (70 cm.), 0.3% (130 cm.), 1.9% (140 cm.), 1.2% (170 cm.), 3.2% (190 cm.), 1.6% (310 cm.).
* *Sambucus*: 0.3% (40 cm.), 0.3% (200 cm.).
Vitis: 0.2% (14 cm.).
Campanula: 0.2% (420 cm.), 0.2% (560 cm.).
Epilobium: 0.6% (460 cm.), 0.3% (580 cm.).

* Identification probable.

Galium: 0.3% (250 cm.), 0.2% (610 cm.), 0.2% (710 cm.).
Gentiana: 0.2% (370 cm.), 0.2% (400 cm.).
Humulus Lupulus: 0.3% (60 cm.).
Labiatae: 0.3% (200 cm.), 0.5% (370 cm.), 0.2% (400 cm.), 0.2% (460 cm.), 0.2% (540 cm.).
Polygonum: 0.3% (330 cm.), 0.3% (350 cm.), 0.4% (400 cm.), 0.3% (520 cm.), 0.2% (560 cm.).
Sanguisorba: 0.2% (400 cm.), 0.2% (500 cm.), 0.4% (520 cm.).
Saxifraga: 0.2% (480 cm.), 0.2% (560 cm.).
Shepherdia canadensis: 0.6% (390 cm.), 0.2% (480 cm.), 0.2% (500 cm.), 0.1% (520 cm.).
Umbelliferae: 0.2% (14 cm.), 0.5% (370 cm.), 0.5% (440 cm.), 0.2% (460 cm.), 0.2% (640 cm.).
Urtica: 0.6% (400 cm.).
Caltha palustris: 0.2% (0 cm.).
Utricularia: 0.2% (420 cm.), 0.2% (460 cm.), 0.2% (580 cm.).
Botrychium: 0.1% (390 cm.), 0.1% (520 cm.).
Selaginella selaginoides: 0.1% (480 cm.).

APPENDIX D

SURFACE POLLEN ASSEMBLAGES FROM BELMONT BOG AND SITES IN NORTHWESTERN PENNSYLVANIA

	BELMONT BOG 1	HEARTS CONTENT	COOK FOREST	TIONESTA SCENIC AREA
Trees, shrubs, herbs *				
Picea	0.2†	—	—	—
Pinus undifferentiated	20.7	11.4	13.7	2.6
P. subg. STROBUS	9.6	12.9	8.7	0.2
Tsuga	4.4	13.8	36.6	59.5
Fagus	2.4	10.0	5.6	10.9
Acer saccharum	2.7	1.8	—	0.6
Tilia	0.4	—	—	—
Fraxinus 4-colpate	1.1	1.5	0.4	0.8
Carya	2.0	1.8	—	—
Quercus	11.8	19.0	11.2	4.5
Ulmus	1.1	0.3	0.2	—
Acer rubrum	4.4	2.9	0.9	3.0
Betula	3.1	14.9	11.7	11.8
Carpinus-Ostrya	2.4	—	—	0.2
Platanus	0.7	0.5	2.5	—
Castanea	0.2	—	—	—
Populus	0.4	—	—	—
Nyssa	0.2	—	—	—
Prunus serotina	0.2	0.3	—	—
Morus	0.2	—	—	—
Liquidambar	—	—	0.2	—
Alnus	0.9	—	0.4	0.8
Salix	1.6	—	—	—